Memorandum

To: Larry Schaffner and Rich Hovde, WSDOT

From: David Hartley and Derek Stuart, **Northwest Hydraulic Consultants**

Date: December 23rd, 2004

Re: Sammamish River Case Study

1 Preface

This memorandum represents one of several deliverables under *Agreement Y-9084, TOD AC – Phase III, Case Studies, Discharge of Stormwater to 5th Order Streams: Definition of Exempt Stream Boundaries in Western Washington.* Case studies were originally planned as reserve Task 17 under Agreement Y-8314, TOD AN; however, this agreement closed on September 20, 2004 and the work has been transferred to TOD AC under provisions of Agreement Y-9084 between WSDOT and Herrera Environmental Consultants, Inc.

Due to the complex and innovative nature of the investigation to determine flow control exemptions for large river systems, an iterative, three-phase approach has been employed. During Phase I work, Herrera Environmental Consultants (Herrera) and Northwest Hydraulic Consultants (NHC) prepared a position paper that presented the theory and justification and synthesized the relevant scientific literature supporting the development of a methodology to exempt river reaches from stormwater flow control based on stream order, cumulative changes in watershed vegetative cover, percent impervious area, stream gradient and tidal influence. Phase II of the project consisted of the development of the methodologies and the application of the methodologies to pilot watersheds. As a result of the Phase II work, the Washington State Department of Ecology has agreed to exempt river reaches from stormwater flow control based on drainage area, cumulative changes in watershed vegetative cover, and percent impervious area.

During Phase III of this project, the methodology developed in Phase II was applied to western Washington to define stream reaches that are exempt from stormwater flow control regulations. Several river systems failed to meet the criteria for exemption and require additional study and refinement of the data in order to correctly apply the criteria. The rivers selected for additional analysis include the Dungeness River, Nisqually River, Sammamish River, Deschutes River and rivers draining portions of Grays Harbor County including the North River and the Chehalis River and its tributaries including the Satsop, Wynoochee, Skookumchuck, Black, Humptulips, and Newaukum rivers. This memorandum documents a case study of the Sammamish River.

2 Context of the Sammamish River Case Study

The Sammamish River drains approximately 100 square miles at its upstream limit at the Lake Sammamish outlet weir, but its LCC (land cover criterion) value of 151.9 exceeds the permissible threshold of 55.4 by a large margin reflecting the large amount of past and potential future urbanization within the river's watershed. The purpose of LCC and the numerical threshold was to define which large, natural, free flowing streams could be expected to remain stable under current and future urbanization, even if no flow control BMPs were implemented anywhere within their drainage areas. The Sammamish River is not typical of the natural, free flowing streams for which the LCC was developed. It is a relatively short, low gradient river connecting Lake Sammamish to Lake Washington that is not particularly vulnerable to channel erosion or instability. For these reasons, exemption of the river from flow control is being reconsidered in spite of its high LCC value.

3 History and Character of the Sammamish River

Martz et al. (1999) provide a good review of the changes made to the Sammamish River since the arrival of Euro-American settlers to the valley in the mid-19th century. At the time of settlement, the valley was densely forested and the river meandered tortuously for approximately 30 miles between Lake Sammamish and Lake Washington. According to Chrzastowski (1983), the river was wider, deeper, and slower moving than today. During the late 1800s, the Sammamish was navigated by steamboats traveling between the two lakes, but during floods, the river would occupy the entire valley, making the main channel difficult to find.

Over the years, the river was straightened numerous times by landowners and communities along its path. By the mid 20-th century, the length of the Sammamish had been reduced by approximately 50%. In the 1960s, the Corps of Engineers and King County further straightened and confined the river channel to protect farm land from spring flooding. This further shortened the river to its current length of 13.6 miles.

According to WRIA 8 Limiting Factors Report (Kerwin, 2001), the Sammamish River valley contained a vast complex of wetlands between the two lakes that were frequently flooded by the meandering river. Construction of the Lake Washington Ship canal, river straightening, bank hardening, drainage and filling of valley wetlands, and river flood control projects have resulted in today's configuration in which the shortened channel no longer meanders, flood flows remain within the confines of channel banks, and the valley land is "well-drained". In all likelihood, the loss of wetlands and their connectivity to the river during high flow has reduced the supply of cooler subsurface water to the channel during low flow. This may be exacerbating episodes of high water temperatures that are considered harmful to migrating adult chinook and sockeye salmon as well as potentially prejudicial to egg to fry survival (Martz et al, 1999). Three segments of the river are on the Federal Clean Water Act 303(d) list of impaired water due to high temperatures.

http://www.ecy.wa.gov/programs/wq/303d/1998/1998_by_wrias.html

4 Past Flow Control Policy in the Sammamish Valley

In its 1990 Surface Water Design manual (SWDM), King County designated the Sammamish River a "major receiving water" along with other major waterways within the county, allowing direct discharge without flow control facilities for projects near the river. This designation was continued through successive updates to the King County manual including their proposed 2004 manual which is designed to be compliant with ESA the 4-d rule. Although other jurisdictions along the river have not been surveyed at this time, it is extremely doubtful that any of them have ever required flow control for areas adjacent to the river that do not drain to tributaries. Although the rationale for designating "major receiving waters" as exempt for flow control is not explicitly provided in the SWDM, the implicit concept is that the rivers and lakes on the list are too large to be negatively impacted from either a flooding or ecological perspective by the relatively small amounts of stormwater that would be generated by development projects near their banks.

5 Lake Levels and River Velocity Analysis

Two potential issues of concern that have been raised regarding designation of the Sammamish River as an exempt reach are potential aggravation of high flood stages in Lake Sammamish caused by backwatering from high flows in the Sammamish River and possible unspecified negative ecological effects from increased river velocities. It is assumed that each of these effects could be caused by increases in future river discharge caused by undetained storm flows entering the river from future development of lands within the Sammamish River valley. In order to assess the potential increases in flood stage and river velocity that could be caused by designation of the Sammamish River as an exempt reach, the following analyses were performed:

1. Flood frequency curves were generated for reaches of the Sammamish bounded by the confluences of the major tributaries using USGS data
2. A land cover change analysis was performed to determine the maximum amount of future effective impervious area that could generate undetained runoff to each of the river reaches.
3. Peak annual flow quantiles for each reach's impervious area were estimated using King County's KCRTS program.
4. A steady-state HEC-RAS model for the entire river from Lake Sammamish to Lake Washington was assembled by combining two existing models for the upper and lower portions of the river.
5. River velocities and lake levels were investigated using the HEC-RAS model for future scenarios corresponding to treating increasing amounts of the river as exempt starting with the portion downstream of the Swamp Creek confluence for one scenario, adding the reach between North Creek and Swamp Creek for the second scenario, and so on, until the whole river was assumed exempt.

6. River velocities for a 1.5 year flood and lake levels for the 100-year flood were compared for each of these scenarios.

5.1 Flood Frequency

Table 1 provides flood frequency estimates for current conditions. Quantiles were determined using the HEC-FFA program to fit a Log-Pearson Type III distribution to peak annual flow data at USGS gage 12125200. Basin area was subsequently used to adjust the frequency curve at the gage to characterize flood quantiles for each major reach of the river.

Table 1. Current Condition Peak Annual Flow Quantiles (cfs)

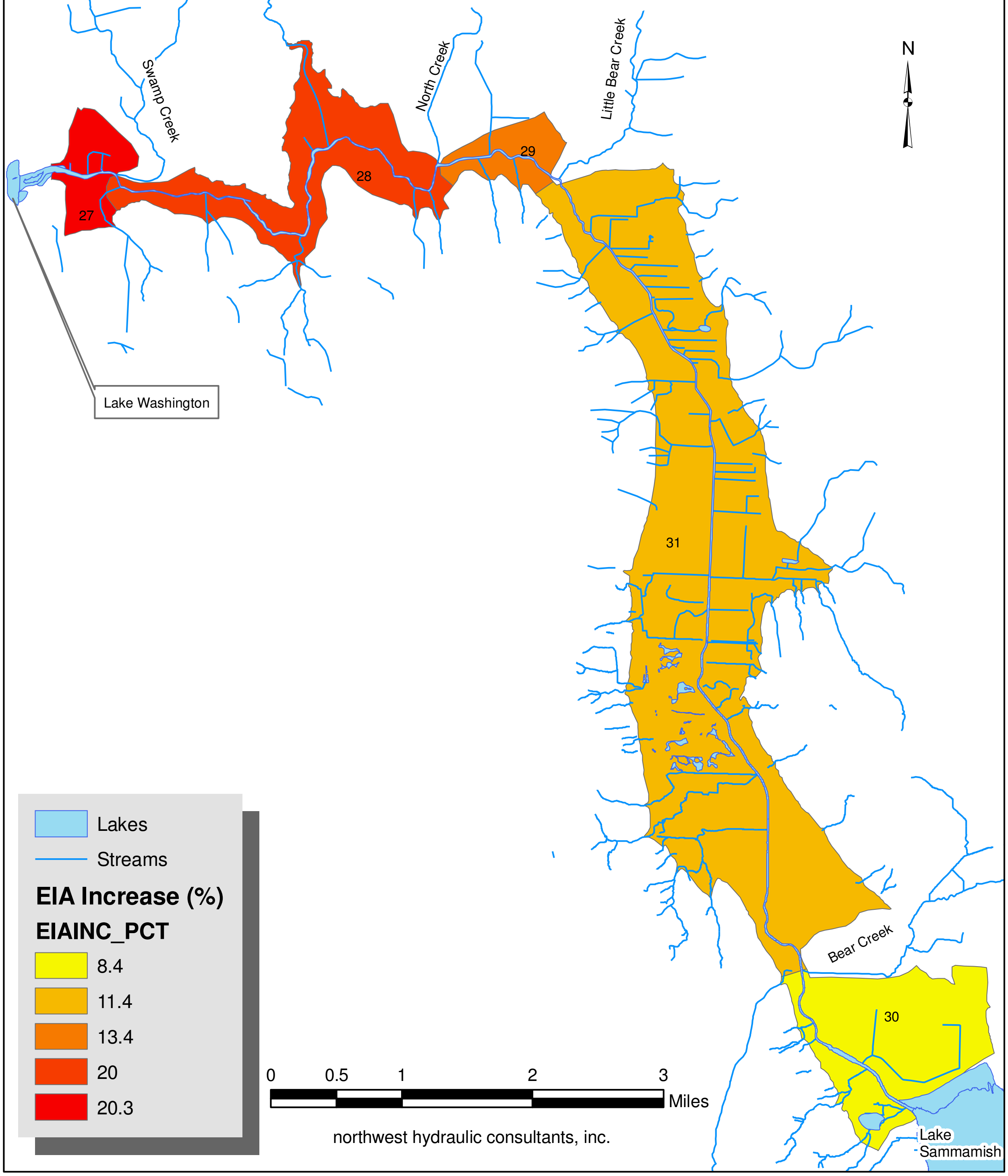
Reach Description	Drainage Area at d.s. limit of reach	1.5-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Sammamish Lake Outlet to Bear Creek Confluence	103	750	862	1093	1209	1335	1370	1401
Bear Creek Confluence to Little Bear Creek Confluence	171	1322	1520	2038	2361	2771	3030	3299
Little Bear Creek Confluence to North Creek Confluence	188	1448	1664	2231	2585	3033	3317	3612
North Creek Confluence to Swamp Creek Confluence	218	1671	1921	2575	2984	3501	3828	4169
Swamp Creek Confluence to Lake Washington	221	1849	2125	2849	3301	3874	4236	4613

5.2 Land Cover Analysis

A land cover analysis was performed on Sammamish River Valley lands adjacent to the river at elevations lower than the 100-foot contour. The analysis utilized an existing land cover classification based on 1998 LANDSAT satellite imagery (Hill et. al., 2000) and compared with expected land use at buildout using current comprehensive plan data made available from the Puget Sound Regional Council earlier in this project. Comparisons were made on pixel by pixel basis using 5 meter pixels to determine potential “forward” development to more intense land use. Increases in effective impervious area (EIA) were determined by zoning in comparison to existing land cover and areas with decreases in EIA were assumed to remain at the current level of development. Total increases in EIA were calculated for each drainage area polygon defined by the Sammamish River reaches listed in Table 1. The results of this analysis are shown in Figure 1 and summarized in Table 2 and Figure 1.

Table 2. Increase in Impervious Area Acreages by Reach			
Reach Description	"Valley" drainage area below 100-ft contour (ac)	Future Impervious Area (ac)	Subbasin I.D. (See Figure 1)
Sammamish Lake Outlet to Bear Creek Confluence	894	76	30
Bear Creek Confluence to Little Bear Creek Confluence	3692	421	31
Little Bear Creek Confluence to North Creek Confluence	214	29	29
North Creek Confluence to Swamp Creek Confluence	823	165	28
Swamp Creek Confluence to Lake Washington	236	48	27

Figure 1: Calculated Change in %EIA from Land Use Change Analysis for Sammamish River Valley Mainstem Sub-Basins



5.3 Hydrologic Analysis of Direct Discharge Impacts

The change in peak annual discharge associated with the potential future increment of impervious area caused by development within the Sammamish River valley was estimated using the King County Runoff Timeseries (KCRTS) program. Changes in peak annual flow quantiles associated with runoff from the future impervious area within the valley portions tributary to each river reach were computed as the difference in peak flow quantile magnitude between a current pasture cover and future impervious area cover. The runoff timeseries from which peaks discharges were extracted was based on an hourly rainfall input and hydrology model time step. Results of the peak change analysis for valley runoff are shown in Table 3.

Table 3. Peak Flow Quantiles and Quantile Changes for 100 acres (cfs)

	1.5-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
EIA	22.0	25.1	30.6	34.3	39.2	42.9	46.7
Pasture	2.5	3.4	5.3	6.7	8.4	9.8	11.3
Peak Increase	19.5	21.7	25.3	27.6	30.8	33.1	35.4

Unit area peak flow increases in Table 3 were combined with impervious area increases from Table 2 to arrive estimates of peak annual flow that would be discharge to the Sammamish River within each reach if the river valley were exempt from flow control requirements. The implicit assumption regarding these direct discharges is that they would all be synchronized when in reality they would to some degree be dispersed because of different travel times from the impervious areas to the river and because of spatial variability of rainfall.

Table 4 recreates Table 1 for a worst case future scenario by simply adding the peak flow quantile increases for each reach to the Table 1 peaks. This not only assumes that increases in runoff from direct discharges would be simultaneous for all valley subbasins, but that they would synchronize completely with peaks in the river; that is, the 100-year peak runoff from exempted future impervious area happens at the same time as the 100-year peak river discharge which also happens everywhere along the river at the same time.

Table 4. Future Peak Annual Flow Quantiles (cfs) as affect by Direct Discharge								
Reach Description	Drainage Area at d.s. limit of reach	1.5-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Sammamish Lake Outlet to Bear Creek Confluence	103	764	878	1112	1230	1358	1395	1428
Bear Creek Confluence to Little Bear Creek Confluence	171	1416	1628	2164	2498	2924	3194	3475
Little Bear Creek Confluence to North Creek Confluence	188	1547	1778	2364	2730	3195	3491	3798
North Creek Confluence to Swamp Creek Confluence	218	1801	2071	2749	3174	3713	4056	4413
Swamp Creek Confluence to Lake Washington	221	1988	2285	3036	3505	4101	4480	4874

Table 5. Future Peak Annual Flow Quantiles % Increase from Future Direct Discharge								
Reach Description	Drainage Area at d.s. limit of reach	1.5-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Sammamish Lake Outlet to Bear Creek Confluence	103	2%	2%	2%	2%	2%	2%	2%
Bear Creek Confluence to Little Bear Creek Confluence	171	7%	7%	6%	6%	6%	5%	5%
Little Bear Creek Confluence to North Creek Confluence	188	7%	7%	6%	6%	5%	5%	5%
North Creek Confluence to Swamp Creek Confluence	218	8%	8%	7%	6%	6%	6%	6%
Swamp Creek Confluence to Lake Washington	221	8%	8%	7%	6%	6%	6%	6%

As shown in Table 5, under the most conservative assumptions, the peak annual flow exceedance levels in the Sammamish River would be increased between 2% at the most upstream reach of the river and 8% downstream of North Creek. These estimates are based on future impervious area from a conservatively large valley area draining directly to the river without flow control. The direct discharge peaks and river peaks are assumed to be temporally coordinated. As will be shown later in this technical memorandum, these conditions are not only highly conservative, they are highly unlikely.

5.4 Hydraulic Analysis of Direct Discharge Impacts

A steady HEC-RAS backwater model of the entire Sammamish River from Lake Washington to Lake Sammamish was assembled from previous models developed by **nhc** for King County (nhc, 1991 and 1992) and as modified by the Corps of Engineers Seattle District. A figure of the HEC-RAS model layout is included in Appendix A. The HEC-RAS model was used to evaluate two issues; first, the sensitivity of Lake Sammamish levels to a range of discharge exemption scenarios, and second, changes in river velocities for more common flood conditions. These analyses utilized current and future peak flow estimates derived in previous sections of this memorandum.

For the investigation of Lake Sammamish levels, 100-year steady discharge conditions were analyzed and for the change in river velocities, 1.5-year conditions were analyzed. The purpose of the lake level analysis was to address concerns raised by King County (personal communication, Jeff Burkey, King County Water and Land Resources Division, September 27, 2004) that exempting the Sammamish River valley from detention would aggravate high lake levels that can potentially damage docks and other shoreline property on Lake Sammamish during infrequent extreme storms. The velocity change analysis at the 1.5 year discharge was made to provide an indicator of approximate increases in river transport capacity during more common flood events.

Several direct discharge scenarios were investigated to develop data for current conditions and for exempting progressively increasing numbers of the reaches moving in an upstream direction from Lake Washington. These scenarios are called “plans” in HEC-RAS. As shown in Table 6, plans P1 through P6 are HEC-RAS results for Lake Sammamish levels during a 100-year event reflecting current conditions and increasing more segments of the river being exempted. The final column is the most significant for the purposes of this memorandum. It shows that under the extremely conservative hydrologic assumptions described above, lakes levels would not increase by more than 0.01 feet if the river were exempted from flow control from the Little Bear Creek confluence downstream to Lake Washington.

Table 6. HEC-RAS 100-yr Results, Lake Sammamish Levels			
Plan		100-yr-W.S. Elev	Change in 100-yr W.S.
		(ft)	(ft)
P1	Current Conditions	31.60	0.00
P2	Exempt from Swamp Creek Down	31.60	0.00
P3	Exempt from North Creek Down	31.61	<0.01
P4	Exempt from Little Bear Creek to Lk. Wa.	31.61	<0.01
P5	Exempt from Big Bear Creek to Lk. Wa.	31.79	<0.19
P6	Exempt Whole River	31.86	<0.26

These results in no way demonstrate that requiring flow control upstream of Little Bear Creek would be effective at arresting increases to Lake Sammamish levels in the future. It does shows that direct discharge downstream of Little Bear Creek would have a negligible impact on Lake Sammamish levels.

Changes in mean reach velocity predicted by HEC-RAS for each different scenario are summarized in Table 7. Under Plan 3 (flow control exemption from the Little Bear Creek confluence downstream to Lake Washington), the maximum change in velocity would occur in the lowest reach between Swamp Creek and Lake Washington where the velocity would increase from 1.25 feet per second to 1.28 feet per second or by 2%. The average velocity in both cases is smaller than 2.0 feet per second, a rule-of-thumb threshold for maintaining transport of sand-sized particles. In this context, the modeled increase for Plan 3 appears insignificant regardless of whether one would interpret increased sand mobility as a positive or negative effect from an ecological perspective. Under Plan 3, further up the river, the HEC-RAS model actually predicts small reductions in velocity. This is a result of the backwater affect of the assumed increased discharge in the lower portion of the river. Even with the most radical flow control exemption scenario (P6), the maximum increases in velocity are in the 5% to 7% range on top of current velocities. All velocities are very moderate from a sediment mobility point of view. A conclusion that could be drawn from these results is that flow exemption in the river could potentially increase fairly low velocities by a small amount and provide at the most marginally more effective transport of fine sediments from the river to Lake Washington.

Table 7. Changes to Reach-Average Velocity under Different Exemption Scenarios				
	Exemption Scenario	1.5-yr Velocity	1.5-yr Velocity Change	1.5-yr Velocity Change
Reach		(ft/s)	(ft/s)	(%)
Lk Sammamish to Big Bear CK	P1	2.40	0.00	0.00%
Big Bear CK to Little Bear Ck	P1	2.65	0.00	0.00%
Little Bear Ck to North Creek	P1	2.71	0.00	0.00%
North Creek to Swamp Creek	P1	2.51	0.00	0.00%
Swamp Ck to Lk Washington	P1	1.22	0.00	0.00%
Lk Sammamish to Big Bear CK	P2	2.31	0.00	0.00%
Big Bear CK to Little Bear Ck	P2	2.65	0.00	-0.01%
Little Bear Ck to North Creek	P2	2.71	0.00	0.00%
North Creek to Swamp Creek	P2	2.51	0.00	-0.01%
Swamp Ck to Lk Washington	P2	1.23	0.01	0.61%
Lk Sammamish to Big Bear CK	P3	2.30	0.00	-0.04%
Big Bear CK to Little Bear Ck	P3	2.64	-0.01	-0.27%
Little Bear Ck to North Creek	P3	2.68	-0.03	-1.03%
North Creek to Swamp Creek	P3	2.54	0.03	1.30%
Swamp Ck to Lk Washington	P3	1.25	0.03	2.00%
Lk Sammamish to Big Bear CK	P4	2.30	0.00	-0.06%
Big Bear CK to Little Bear Ck	P4	2.64	-0.01	-0.35%
Little Bear Ck to North Creek	P4	2.68	-0.02	-0.84%
North Creek to Swamp Creek	P4	2.54	0.04	1.49%
Swamp Ck to Lk Washington	P4	1.26	0.03	2.49%
Lk Sammamish to Big Bear CK	P5	2.24	-0.07	-3.01%
Big Bear CK to Little Bear Ck	P5	2.70	0.05	1.93%
Little Bear Ck to North Creek	P5	2.74	0.04	1.32%
North Creek to Swamp Creek	P5	2.63	0.12	4.65%
Swamp Ck to Lk Washington	P5	1.31	0.08	6.23%
Lk Sammamish to Big Bear CK	P6	2.25	-0.05	-2.35%
Big Bear CK to Little Bear Ck	P6	2.71	0.06	2.35%
Little Bear Ck to North Creek	P6	2.75	0.05	1.73%
North Creek to Swamp Creek	P6	2.64	0.14	5.21%
Swamp Ck to Lk Washington	P6	1.31	0.09	6.85%

6 Timing of Peak Flows in the Sammamish River

The foregoing analysis of the sensitivity of Lake Sammamish flood levels and river velocities to flow control exemption scenarios has been predicated on a steady state analysis that assumes the simultaneity of peak stormwater discharges from exempted impervious area in the river valley and peak flow in the Sammamish River. In reality, the these estimates of increases in river flood quantiles associated with exempted future impervious area are likely to be overly conservative; that is, much higher than will actually occur.

Peak stormwater flow generated from impervious area that is exempt from flow control can be expected to discharge to the river within an hour of peak rainfall. Based on the HEC-RAS results, a typical travel time within the river is approximately eight hours from the Lake Sammamish to Lake Washington. Stormwater peaks entering the upstream end of the river may take several hours to reach Lake Washington and would not be likely "catch up" with stormwater peaks entering further downstream. Additionally, all stormwater peaks, regardless of outfall location along the river would be expected to exit the river within half a day of the peak rainfall that generated the stormwater runoff. Peak flows in the Sammamish River, on the other hand, are expected to be more delayed with respect to their causative storms because of the elongated shape of the watershed, greater travel distances, flood attenuation by forest areas and by Lake Sammamish. Therefore it seems quite possible that undetained stormwater peaks from exempted impervious area in the valley of the river would enter and leave the river before the time when flood peaks occur in the river.

In order to substantiate the hypothesis that the flood impacts of impervious area discharges significantly precede and are decoupled form river peaks, both the historical record of Sammamish River peak annual floods and total daily precipitation records were compared. Table 8 illustrates the time correlation between lowland rainfall and peak discharge in the Sammamish River. Peak flow data are from the currently operating USGS gage 12125200, Sammamish River near Woodinville with the exception of water year 1951 which is from the discontinued USGS gage 12125000, Sammamish River near Redmond. Both gage sites are between Bear Creek and Little Bear Creek confluences on the river. All peaks of record greater than the median annual flood of 1520 cfs are included in the table. Precipitation data is from the NWS record at Seatac Airport.

As shown in Table 8, a majority of 11 out of the 18 dates on which river peaks occurred, daily precipitation was less than 0.50 inches. In contrast, one or two days prior to the river peaks, recorded daily precipitation depth exceeded 1.0 inches for 12 out of 18 of peak flow events. On three of the days when the five largest floods of record occurred, zero rainfall was recorded and the maximum daily rainfall occurring on the two non-zero precipitation days was only 0.55 inches. In contrast, total rainfall depth at Seatac one day prior to the five largest floods ranged from 1.29 to 3.06 inches and on four out of five days was greater than 2.50 inches. From these data, it is clear that peak flows on the Sammamish River typically lag lowland storm events by at least one day and that on the day river peaks occur, often zero or much less significant rainfall occurs. The lag in the river's response is primarily the result of storage of flood flows in Lake Sammamish and secondarily the delay in discharges reaching the lake and the river from the two largest tributaries, Issaquah Creek and Bear Creek.

In general, infiltration of storm runoff is the preferred stormwater management practice for maintaining natural flow patterns in a watershed, and this is certainly true for the Sammamish River valley because the maintenance or enhancement of cooler groundwater flow to the river would be beneficial for the river's water quality. Stormwater infiltration should be practiced in the Sammamish River valley to the maximum extent feasible. For stormwater quantities in excess of what it is feasible to infiltrate, it would likely be preferable to directly discharge to the river. The benefit of routing impervious area discharges through from the river valley through detention ponds to control peak flow or high flow durations is dubious at best and may be counter productive because of the evident lag in the river's response. Indeed, if there was ever case for allowing direct discharge of stormwater to river segments in the lower portion of a watershed in order to release runoff from a river in advance of a flood, this would seem to be it.

Table 8. Correlation of Sammamish River Peak Flows with Day of Lowland Rainfall

Water Year	Date of Peak	Peak Q (cfs)	Rank	Daily P on Peak Date (in)	Daily P one day prior (in)	Daily P two days prior (in)
1951	11-Feb-51	1,520	18	0.14	0.46	2.98
1969	7-Jan-69	1760	9	0.01	0.71	0.61
1972	6-Mar-72	2390	3	0.00	2.70	0.40
1973	28-Dec-72	1740	10	0.04	0.53	0.89
1974	19-Jan-74	1640	14	0.15	0.71	0.00
1976	4-Dec-75	2070	6	0.07	1.06	1.75
1978	16-Dec-77	1580	16	0.00	1.08	0.36
1980	21-Dec-79	1670	12	0.76	0.04	0.49
1982	18-Feb-82	1770	8	0.51	0.41	0.52
1983	5-Jan-83	1720	11	1.19	1.35	0.41
1984	20-Nov-83	1590	15	0.57	0.61	0.00
1986	19-Jan-86	2320	4	0.00	2.98	0.50
1987	24-Nov-86	1530	17	1.34	2.49	0.06
1990	10-Jan-90	2190	5	0.00	2.83	0.40
1991	5-Apr-91	1780	7	0.70	2.64	1.46
1996	9-Feb-96	2470	2	0.55	3.06	0.72
1997	1-Jan-97	2870	1	0.37	1.29	0.64
2002	17-Dec-01	1670	13	0.00	1.21	0.52

7 Summary and Conclusions

The Sammamish River failed the land cover criterion (LCC) for exempting large streams from flow control because of relatively high levels of current and future urbanization in the river's watershed. However, because the river is of relatively low gradient and is not susceptible to erosion and channel instability, additional analysis was performed to determine the hydrologic and hydraulic consequences of flow control exemption for future impervious area within the Sammamish River Valley. An approximate hydrologic and hydraulic analysis using the KCRTS and steady HEC-RAS models under extremely conservative assumptions indicates that the 100-year flood level in Lake Sammamish would not be measurably increased by a flow control exemption applied to the river downstream of the Little Bear Creek confluence. This same exemption scenario was shown to have an insignificant effect on river velocities.

A comparison of peak annual flow data for the Sammamish River and daily precipitation data from Seatac Airport strongly support the hypothesis that river flood peaks occur at least a day later than lowland storm events and associated peak stormwater runoff from impervious surfaces. This indicates that direct discharges of stormwater peaks from exempted impervious areas to the river will exit the river well in advance of the time when flood peaks occur. Additionally, these river timing characteristics suggest that flow control facilities are not useful for peak flow control and are highly questionable for duration control as well.

Conservative assumptions were combined with approximate hydrologic and hydraulic methods for this study. A more rigorous, time consuming, and expensive analysis of the Sammamish River hydrology and hydraulics both with and without flow control facilities in the valley could be made by performing long term, continuous hydrologic simulation of the entire watershed under future land cover conditions. Results of this hydrologic modeling could then be used as boundary conditions for <u>unsteady</u> hydraulic routing of a range of historical floods using HEC-RAS-Unsteady or FEQ. These models would provide more accurate and detailed estimates of flood discharges, stages and velocities throughout the length of the river under different flow exemption scenarios. While such an analysis would be technically satisfying, it is not expected that the conclusions arrived at would be different from the ones found here.

For runoff that cannot be infiltrated to augment groundwater discharge, the results of this study support a flow control exemption for the Sammamish River from the Little Bear Creek confluence to the river mouth at Lake Washington. Results also suggest that an exemption applied to the full length of the river would have at most very moderate impacts on 100-year lake levels and changes in river velocity.

8 Recommendations

- Maximize infiltration of stormwater to the Sammamish River Valley
- For stormwater that can not be infiltrated, allow direct discharge of runoff to the reach of the Sammamish River from the Little Bear Creek confluence to the river mouth at Lake Washington.

- In the future, apply more detailed modeling to evaluating extending the direct discharge reach upstream to Big Bear Creek or the head of the river at the Lake Sammamish Weir.

9 References

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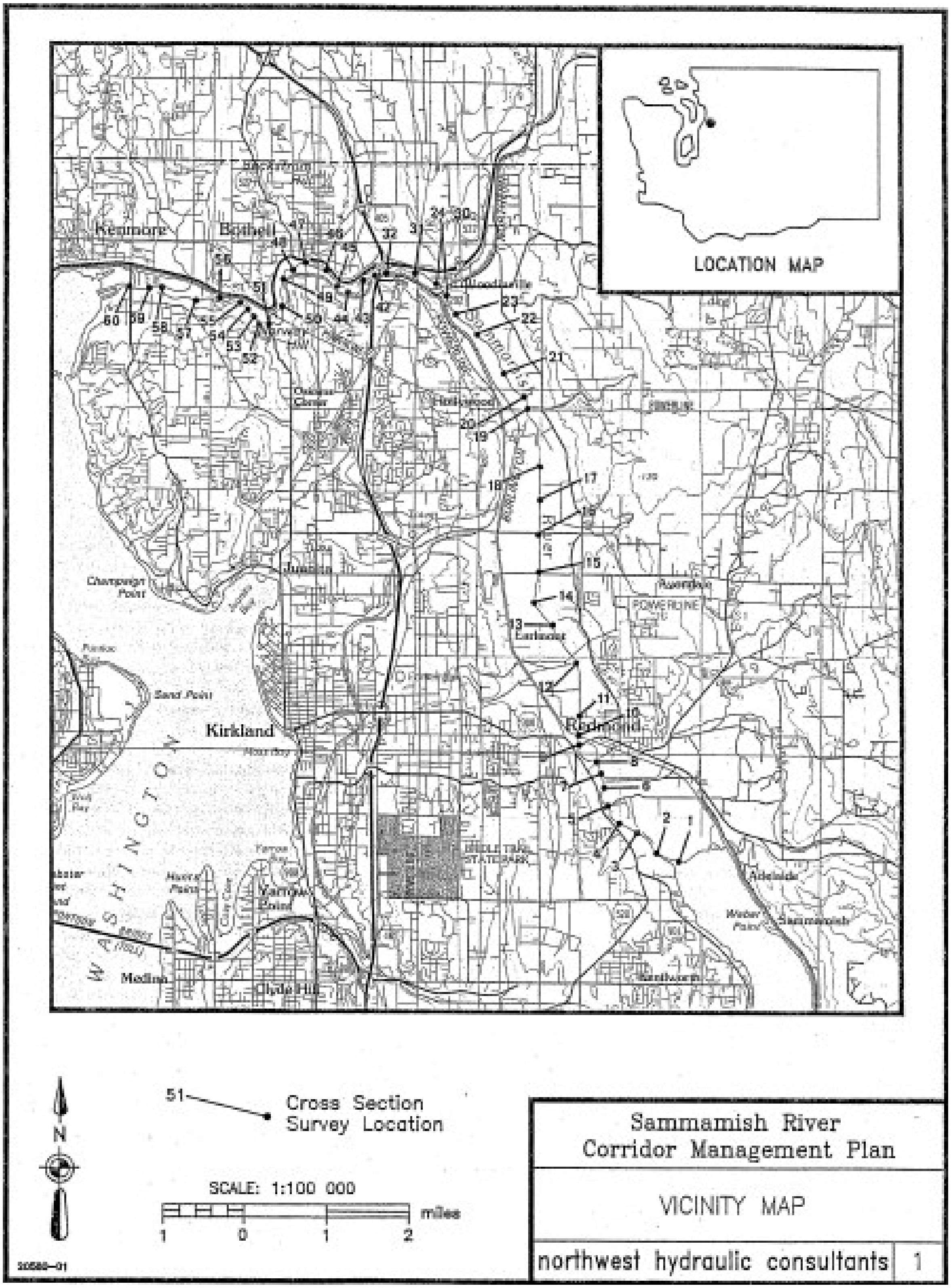
Appendix A


LOCATION MAP
Kenmore
Bothell
Kirkland
Redmond
Juanita
Medina
Clyde Hill
WASHINGTON
51— Cross Section Survey Location
SCALE: 1:100 000
miles
N
Sammamish River Corridor Management Plan
VICINITY MAP
northwest hydraulic consultants
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